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16. ABSTRACT

This paper summarizes the Technical Resource Document (TRD) of the same title (EPA/600/2-84/040, March 1984). Although the TRD specifically addresses construction of hazardous waste disposal facilities in the United States, most information is universally applicable. The geotechnical parameters the permittee should test, observe, and document during constrution, operation, and closure of a disposal facility are identified, as are: limitation of design properties tests; applicability of index properties tests; statistical analysis of sampling size, frequency, and distribution to support a quality assuracne program; commonly used test methods and the criteria for their selection; and a quality assurance program for the permittee of a hazardous waste disposal facility.

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GEOTECHNICAL QUALITY ASSURANCE OF CONSTRUCTION OF DISPOSAL FACILITIES

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This paper summarizes the technical resource document of the same name (U.S. EPA-600/S2-84-040, March 1984). Although the technical resource document is specifically addressed to the construction of hazardous waste disposal facilities within the U.S.A., most of the topics discussed and most of the general suggestions made are of universal applicability. The need for a quality assurance programme as a management practice which assures the protection of the human health and environment is discussed within the framework of the EPA regulations promulgated on 26 July 1982. The permittee of a hazardous waste disposal facility is shown to be somewhat unique in the construction industry given the three responsibilities, design, construction and operations, and quality assurance, all consolidated with him. The geotechnical parameters which should be tested, observed and documented during the construction, operation and closure of a disposal facility are identified. The limitations of design properties tests and the applicability of index properties tests are discussed. A summarized statistical analysis of sampling size, frequency and distribution to support a hazardous waste disposal facility quality assurance programme is presented. Accepted and commonly used methods for testing water content, unit weight, specific gravity, grain-size distribution, liquid limit, plastic limit, cohesive soil consistency, water content/density/compactive effort, cohesionless soil relative density, and geomembranes/geotextiles are identified. The criteria for the selection of a particular test method are discussed. A quality assurance programme, suitable for the somewhat unique permittee of a hazardous waste disposal facility, is presented. Considerations for such a quality assurance programme are also addressed.

Key Words—Hazardous waste, disposal facility, landfill, surface impoundment, land treatment, test methods, U.S.A., assurance, inspection, quality documentation, geotechnical parameters.

1. Introduction

As stated in the *Federal Register* (EPA 1982).

> EPA wants to make sure that the issuance of an RCRA (Resource Conservation and Recovery Act) permit for a facility means that a certain level of protection is provided and that the public can be assured that the prescribed level of protection will be achieved.
>
> Section 3004 of RCRA provides that EPA has authority to issue regulations covering owners or operators of (hazardous waste) treatment, storage and disposal facilities as may be necessary to protect human health and the environment.

Given this authority the EPA has charted a two "line of defense" protection strategy for hazardous waste disposal facilities. This strategy calls for facility design and operating standards to prevent contamination and a monitoring and response

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programme to detect and correct a condition of contamination should it occur. The EPA believes that adequate protection will be afforded if the technical and environmental performance standards promulgated, to execute their two 'line of defense' strategy, are met. A quality assurance programme for the construction, operation and closure of a hazardous waste disposal facility, though not mandated by the current regulations, is a "management practice" which can assure that these standards are met, that the strategy is executed and that human health and the environment are protected.

1.1 *Objective of study*

The study is intended to provide technical background for use by designers, specifiers, quality assurance engineers, and permit writers. It addresses the subject of quality assurance of site geotechnical parameters during the construction, operation, and closure of landfills, surface impoundments, waste piles, and land treatment units. It does *not* address injection wells or seepage facilities.

1.2 *Scope of the study*

Four major topics are discussed as they relate to the responsibilities of the permittee during construction, operation, and closure of a hazardous waste disposal facility.

(1) Those geotechnical parameters that *should* be tested and/or observed and documented are identified and described. The reasoning for their selection is given.

(2) Sampling and frequency of testing are discussed. Random sampling plans, sample size selection, and calibration of test equipment are presented using rational, unbiased statistical methods.

(3) The commonly used laboratory and field testing and/or observation methods, needed for investigation of the geotechnical parameters, are identified and described. A discussion of merits and limitations of the various methods is given. Criteria are proposed for selection among alternatives.

(4) A quality assurance programme, suited to the unique construction responsibilities of the permittee, is presented and discussed. The documentation necessary to provide a valid record of the quality of the work is recommended.

1.3. *The unique permittee*

In most areas of construction there is a contractual relationship between the owner, whether public or private, and the contractor. The owner's designers prepare plans and specifications. The contractor is expected to use those "control of quality" procedures necessary to control his materials and workmanship to comply with the plans and specifications. The owner's inspectors perform those acceptance sampling and testing functions necessary to give confidence to the owner that the materials and workmanship provided are acceptable. This then results in a near adversary relationship between the owner and the contractor.

The permittee of a hazardous waste disposal facility is somewhat unique in the construction industry. Because of EPA policy, the permittee is responsible to the EPA for all three construction related functions:

(1) The design function: including site selection, site characterization, analysis and

design, plans and specifications, preparation of the permit application, and verification of design for exposed site media.

(2) The construction and operations function: provision of all materials and workmanship.

(3) The inspection function: all quality assurance activities, including sampling, testing and/or observation, and documentation.

That he is responsible for both construction and inspection poses a potential conflict of interest. The quality assurance programme presented later in this paper accounts for the permittee's unique situation and this potential conflict of interest.

2. Geotechnical parameters

In the design of a hazardous waste disposal facility the permittee's design group makes estimates of the engineering properties of the constructor-placed materials. This requires quantitative and specific information on the physical and strength properties of soils that have direct and valid application to the design problem (ASTM 1970). These properties include permeability, compressibility, and shear strength. The function of the quality assurance programme during construction is to assure the standard of quality specified by the design is achieved. Ideally, quality assurance observations and tests *should* measure the design properties directly.

2.1. *Design properties tests*

The geotechnical tests used to define the engineering properties of soils are

Permeability (laboratory permeability tests, laboratory capillarity tests, and field permeability tests).

Compressibility (laboratory consolidation tests and swell pressure tests).

Shear strength (laboratory direct shear, laboratory triaxial compression, and laboratory unconfined compression).

2.2. *Limitations of design properties tests*

Although these are the tests that *should* be made as part of a quality assurance programme, they are not normally used because they require the following (ASTM 1970; Department of the Army 1970; Terzaghi 1967).

(a) Extensive time: the performance of any of these tests can take from one full day to as long as two weeks. Efficient control of construction requires much faster test times.

(b) Complex equipment.

(c) Complex procedures.

(d) Highly trained operators.

(e) Controlled laboratory environment. This implies temperature control and vibration-free surroundings not normally found at a construction site.

(f) High quality undisturbed samples.

Instead, various simpler, faster, index tests, whose results relate to permeability, compressibility and shear strength, are performed.

2.3. *Criteria for inspection tests and observations*

Construction efficiency and control of quality require that nearly continuous tests and observations be made during the progress of the work. Therefore, an inspection test or observation should conform to the following.

(a) It should be a good indicator of a design property and should correlate well with the appropriate engineering design property by itself or with other, similar tests.

(b) It should be accurate and precise. Accuracy can be improved by calibration and should be stable. Precision should be within acceptable, known limits.

(c) The results should be quickly available. The test or observation should be capable of being performed in time for an acceptance decision to be made so that minimum interference with contractor performance occurs.

(d) It should be easily run using simple, rugged equipment. The test or observation should not require extensive training of the operator or require judgement decisions on his part.

(e) An undisturbed sample, except for density, should not be required.

(f) It should provide test/observation results that are documentable. The test or observation should be a number or a well defined term or phrase.

(g) Preferably, the test/observation should be non-destructive. Field tests often require sample removal and replacement or patching.

2.4. *Index properties tests*

In the practice of geotechnical engineering, there has been developed a small group of laboratory tests called indicator, on index properties, tests. These are physical tests that have proven to be suitable for quality assurance programmes, and some of which have been used in such and similar applications for over 50 years. (Peck *et al.* 1974).

The index properties tests useful in a quality assurance programme may be placed into three categories.

(1) Weight–volume relationships:
water content test;
density test;
specific gravity test;
calculated values—void ratio, porosity, and degree of saturation.

(2) Soil classification tests:
grain size distribution tests;
Atterberg limits tests;
consistency tests—using simple field methods;
calculated values—plasticity index, liquidity index, activity, and USCS Classification.

(3) Laboratory compaction:
density/water content/compactive effort tests, for cohesive soils and "dirty" granular soils;
maximum and minimum density tests, for clean granular soils.

All of the index properties result from standardized soils tests.

2.5. *Construction processes*

The main tests/observations that *should* be made for the various construction

processes are described below. The emphasis is on a quality assurance programme that focuses on catching mistakes before or as they occur, correcting them, testing for specification compliance, and documenting the entire process to provide the necessary confidence in the inspection procedure. This requires continuous, cooperative interaction between the design group, the construction group, and the inspection group. The tests and/or observations that should be made and documented are as follows.

(1) Site preparation:
observation of the newly exposed ground surface to confirm site characterization;
observation of surface drainage contouring;
observation of behaviour of the drainage system.
(2) Excavation:
observation of exposed walls and floor for site media verification;
observe construction surveys for exact trench locations and slopes;
observation of excavation related soil movements, using surveying methods;
observation of placement of erosion control measures.
(3) Foundation preparation:
observation of stripping;
observation of soil and rock surfaces;
observation of construction of underseepage cutoffs.
(4) Compacted earth fill:
quality of the borrow soils;
atmospheric conditions recorded;
equipment suitability;
lift thickness;
compactive effort (number of passes) and uniformity of rolling;
compacted density and water content.
(5) Liner materials and geotextiles:
identification of materials used;
for admixed materials, the application rate, blending, spreading, rolling, layer thickness, and density (see Compacted earth fill above);
for geomembranes and geotextiles, the identification of material, smoothness of placement surface, method of placement, and imperfections;
for geomembranes and geotextiles, the seam overlap, seam sealing, and seam integrity tests.
(6) Hydraulic collector:
observation of the surface of the impermeable base for imperfections;
observation of the amount and direction of slope;
quality of permeable materials;
tests of placement of granular materials.

3. Sampling techniques

The method and frequency of sampling and testing in construction had traditionally been based on intuitive decisions of the sampler or his superiors. The purpose of sampling and testing is to provide data for evaluation of a portion of the work. Unless sampled by probability, or random, sampling methods, the result is often a biased and nonrepresentative estimate of a quality characteristic. Frequency of sampling and testing can only be rationally discussed in statistical analysis terms. It is a function

of desired level of confidence, maximum error or % error, and the actual variability of the tested quality characteristic in the sampled portion of work. Comparison of standard and alternative test methods can be made on the basis of sample sizes needed for equivalence of confidence levels.

3.1. *Frequency of sampling and testing*

There is an inherent variability in measurement data for any specified quality characteristic of any soil mass, whether natural or construction-processed. Variability in measurements occurs as a result of (a) material composition variability, (b) placement (formation) process variability, and (c) measurement process variability. All measurements contain variability from all three causes combined.

The difference or error between the measured value and the "true" or reference value is the sum of components, an accuracy (systematic or calibration) error or bias and a precision (random) error.

Accuracy refers to the degree of agreement of individual measurements or the average of a large number of measurements with a "true" or accepted reference value. This implies the idea of a consistent deviation, or *systematic* or *bias* error, which is fixed or common contribution to error in each of a sample of measurements. *Precision* is the degree of mutual agreement among individual measurements of a consistent material made under prescribed, like conditions. The *imprecision* of measurement may be characterized by the standard deviation of the errors of measurement σ_T.

Because the effects of material composition, placement process, and testing process are interrelated, it is not usually possible to differentiate these in a group of measurements and only the overall standard deviation can be determined from the measurement data. The material composition and placement process effects are usually combined into a *material quality* standard deviation, σ_Q.

When material quality is uniform (low σ_Q) the precision of the test method (σ_T) is of great importance to overall standard deviation. However, when material quality is not uniform (high σ_Q) the relative precision of one test method versus another is of little overall importance.

3.2. *Types of sampling*

Probably the most satisfying method to the engineer concerned about sampling all parts of a block of construction is a combination of (a) stratified random sampling and (b) systematic sampling with a random start.

If a universe, or construction block, consists of, or can be divided into, a group of strata, then a random sample can be drawn from each stratum instead of drawing a single random sample from the entire population. This is called *stratified random sampling*. The division of a soil mass or a construction process into blocks is a form of stratified random sampling.

A popular sampling method is *systematic sampling with a random start*. This method involves the selection of successive sample units at uniform intervals of time, distance, area, or volume. It is argued that if the first sample unit is selected at a random location, then all successive units are random also.

By subdividing each block of work into a convenient large number of sub-blocks, using a random start, and following a systematic pattern, a random sample with uniform coverage of the block is obtained.

3.3. *Selection of sample size*

A statistically rational and valid method of selecting sample size is given in ASTM (1982) Designation E 122-72, Standard Recommended Practice for Choice of Sample Size to Estimate the Average Quality of a Lot or Process. The equation for the number of units (sample size, n) to include in a sample in order to estimate, with a prescribed precision, the average of some characteristic of a lot is.

$$n = (t\sigma'/E)^2, \tag{1}$$

or, in terms of coefficient of variation,

$$n = (tV'/e)^2 \tag{2}$$

where n = number of units in the sample;
t = a probability factor, from the Tables of Students' t for the prescribed precision;
σ' = the known or estimated true value of the standard deviation of the universe or lot;
E = the maximum allowable error between the estimate to be made from the sample and the result of measuring (by the same methods) all the units in the lot;
V' = coefficient of variation = $\sigma'\bar{X}$, the known or estimated true value of the universe or lot;
$e = E/\bar{X}$, the allowable sampling error expressed as a percent (or fraction) of $\bar{X}$;
$\bar{X}$ = the expected (mean) value of the characteristic being measured.

4. Testing

Previously in this paper the geotechnical parameters, that should be observed or tested during the construction of a disposal facility, were identified. (For the purpose of this paper, an *observation* usually does not involve a formal or specific method, whereas a *test* almost always involves a specific technique and often a specific piece of equipment.) Standard laboratory or field test methods exist for each of the soil index properties that were identified and defined.

This section of the paper identifies the standard test methods for the soil index properties. For most of these, there exist commonly used alternative test methods; these are also identified. The following discussion includes only those tests that were identified earlier in the paper. They are the ones considered most appropriate for both process control and acceptance inspection during construction. Although not discussed here, other tests may be used for special investigations during construction, but usually not on a routine basis. These include such tests as the engineering properties tests (mentioned earlier), geochemical tests, hydrology-related tests, off-site evaluations of off-site materials, and material-specific tests of nonsoil materials such as portland cement, asphalt, bentonite, and others.

4.1. *Criteria for test method selection*

With the exception of the nuclear gauge moisture/density test, the density part of volumetric field density tests, the air lance test, the vacuum seam test and the conductivity test, all of the standard test methods require (a) procurement of a sample from the field and (b) performance of a test in a laboratory environment. This usually involves the

availability of electric power, a water supply, freedom from dust and vibration, and controlled temperature and humidity. These are conditions found in a central testing laboratory, and are available only in a few well-equipped construction site laboratories, usually found only on large construction projects. In response to this, and for the other reasons given below, alternatives to the standard test methods have come into common use for construction quality control. The criteria for selection among alternatives include the following.

(a) Time; speed of testing and/or speed of obtaining test results. The efficient use of men and machinery on a construction site demands that the results of quality control testing be available quickly. Construction costs can be U.S. $100 per hour or more. The cost of rapid testing must be compared to the total cost to the permittee due to a slower test method.

(b) Correlation with the standard test method. A reasonable reproducibility of test results must be obtainable if test operator or specific test equipment is changed. Accuracy must be stable so that a calibration correction can be made; precision must be such that a reasonable number of tests can be averaged to yield the required confidence.

(c) Adaptability to field laboratory conditions. The absence of electric power, the absence of water, and/or the absence of environmental controls can effectively eliminate certain standard test techniques.

(d) Adaptability to on-site use. For example, soil density is more readily measured in place rather than by use of an undisturbed sampling method with laboratory measurement of density.

(e) Equipment cost; comparison can be made in terms of capital cost of test equipment, relative operator cost, cost of field laboratory services, and need for rapid test method. Expensive, automated equipment cannot be justified if less costly apparatus will provide equivalent results in sufficient time for effective action, especially during small, slow-moving construction processes.

(f) Simplicity and ruggedness of equipment; acceptable precision and sensitivity of equipment can often be achieved with apparatus that is simpler to use and more durable under field conditions than more sophisticated devices. The level of necessary operator training, and operator fatigue and/or boredom, can seriously affect repeatability of a test method.

(g) Nondestructive testing; this is of particular importance where the act of sampling causes a discontinuity that must be repaired. For example, securing a test coupon from a geomembrane seam requires placement of a secure patch to maintain impermeability.

4.2. *Soil index properties test methods*

The listing given in Table 1 includes the standard laboratory test method for each of the index properties. In most instances, alternative standard or non-standard methods are in common use. There are undoubtedly other alternative methods for some of the tests that are used by various testing groups for construction control; however, they are not as well known, well documented, well used, and well accepted as those identified.

4.3. *Observation techniques*

Observations are not dependent on the specifics of a particular technique. Most involve visual evaluations, or simple counting and tabulation, or are simple length or thickness

TABLE 1
Laboratory test methods

Water content	Unit weight	Specific gravity	Grain-size distribution	Liquid limit	Plastic limit	Cohesive soil consistency	Water content	Cohesionless soil rel. density	Geomembrane/ geotextile
Oven dry (D 2216)*	S Lab. volumetric	S Lab. method (D 854)	S Sieve +200 μm (D 422)	S Multi-point (D 423)	S Lab. method (D 424)	S Unconfined compression (D 2166)	25-blow S Proctor (D 698)	S Lab. max. (D 2049)	Bonded seam strength (D 3083)
Nuclear moisture/ density (D 3017)	S Lab. displacement		Finer than 200 μm (D 422)	S One-point (D 423)		Field unconfined compression	Non-S Proctor (D 1557)	S Lab. min (D 2049)	Breaking strength (D 751)
Gas burner frying pan	S Field sand cone (D 1566)		S hydrometer (− 200 μm fraction) (D 422)			Hand penetrometer	One-point Proctor	Modified Providence	Peel adhesion (D 413)
Alcohol burning	S Field rubber balloon (D 2167)		Pipette for silt and clay			Hand-held Torvane	Two-point Proctor		Air lance
Calcium carbide—speedy	S Field drive cylinder (D 2937)		Decantation for silt and clay				Hilf's rapid		Vacuum seam
Infrared oven	S Nuclear moisture/ density (D 2922)						Ohio Highway Dept. curves		Conductivity
Hot air oven							Harvard miniature		

*Items in parentheses indicate ASTM (1982) test numbers.
†S = Standard.

measurements. The usual procedures for these observations are either straightforward, requiring no special instruction or equipment, or they involve visual comparisons that are either site-specific or material-specific. Specification writers and permit writers should simply state the desired end result and leave the determination of technique to the experience and ingenuity of the inspector or his superior.

As an example of the statements made above, the smoothness and freedom from sharp objects of the soil surface to receive a geomembrane can only be accomplished by 100% visual inspection. This is also true in the observation for freedom of the placed membrane from tears. The thickness of a soil lift prior to compaction can be quickly and easily checked with a marked rod, or even a suitably marked spade. The observation of a freshly cut trench wall or floor starts with visual inspection for texture and colour patterns, supplemented by field expedient soils tests using the visual–manual procedure. Sampling and testing plans for site media verification studies can then be effectively made. The results of the observation depend more on the technical expertise and willingness of the inspector than on specific details of technique.

5. The quality assurance programme

As stated earlier in this report the permittee of a hazardous waste disposal facility is somewhat unique in the construction industry. Because of his unique situation the permittee is confronted with a potential conflict of interest between his construction and operations responsibility and his quality assurance responsibility.

Those factors that make his situation unique, and that affect the quality assurance programme, are listed below.

(1) The permittee has *total* responsibility for design, construction, and inspection within his own organization.

(2) The permittee must give confidence, or assurance, to the EPA in the quality of his work.

(3) The permittee passes judgement on his own work.

(4) A disposal facility can be relatively small project with only a few workmen and pieces of equipment operating at any time.

(5) The permittee's organization is relatively informal, with sometimes blurred lines of authority and responsibility.

5.1. *Considerations for a quality assurance programme*

The permittee should consider all of the following before establishing a quality assurance plan: quality personnel management; attitude of the workmen, construction management, and inspectors towards quality; the nature and cost of a quality assurance programme; the human factor; and the problem of scale.

5.1.1. *Quality personnel management within the permittee's organization*

The permittee can be assured that his desired standard of quality is achieved by the implementation of an effective quality assurance programme within his organization. Such a programme would undoubtedly include management practices with the objective of effecting worker performance.

For the purpose of this paper, the implementation of management practices to

effect worker performance, such as those recommended by Harris & Chaney (1969), shall be called *quality personnel management*. Quality personnel management includes but is not limited to practices such as proper supervision, personnel selection, inspection techniques, and quality assurance jobs definitions. It also includes measures to enhance worker education, participation and satisfaction. It includes other positive motivators such as measures to enhance worker identification with the work, including having workers sign their work. It also includes negative motivators which "push" towards the desired standard, e.g. the threat of a reprimand, as opposed to positive motivators which "pull". In summary, quality personnel management includes all the management practices which effect worker performance to give a measure of assurance that the desired standard of quality is achieved.

Quality personnel management within the permittee's organization is a responsibility of the permittee. Also quality personnel management within the permittee's organization is, in general, of no more peculiar significance in the construction of a hazardous waste disposal facility than it would be in any other construction endeavour undertaken by the permittee's organization.

5.1.2. *Workman/management/inspector attitude towards quality*

The individual workman is the ultimate determinant of quality. There is a continual conflict between his desire to achieve high productivity and to do the work "right" as he knows it. He, and his supervisors, may feel that the project is overdesigned at times. They may then develop a "rebel" attitude, in which they will show the inspector that they have as much knowledge as the designers.

The inspector can be part of a team or can be the adversary of construction. He may develop a bias towards or against the construction group. The inspector must be qualified for his work and must not be given the job as a reward for long service.

5.1.3. *The nature of a quality assurance programme*

The nature of a quality assurance programme should match the nature of the design. That is, the design for a relatively high standard of quality (e.g. for a site where the complex geology and the protection of the human health and environment require that extensive measures be undertaken) calls for a programme which gives a great deal of assurance that the high standard of quality is achieved. Conversely, the design for a lesser standard of quality (e.g. for a site with an ideal geology and climatic conditions, and where little threat is posed to the protection of the human health and environment) does not call for that same programme which gives that great deal of assurance that this lesser standard of quality is achieved. Simply stated, a design for a relatively high standard of quality calls for a programme which gives a high assurance that the standard is achieved. And a design for a relatively low standard of quality calls for a programme which gives a lesser, but sufficient, assurance that the standard is achieved.

5.1.4. *The human factor*

There can never be absolute certainty that the desired quality is everywhere achieved in the construction of a hazardous waste disposal facility. There exist too many variables, particularly given the inevitable gaps in our knowledge of the soil con-

ditions. However, a quality assurance programme does give a measure of assurance, of confidence, that the standard of quality desired and designed for is achieved. The better the quality assurance programme the greater this measure of confidence can be. And given the EPA's two-pronged, prevention and cure, protection strategy, the inevitable uncertainty of the quality has been accounted for by the regulatory provision of the monitoring and remedial action procedures.

One significant variable that can be addressed and limited by a quality assurance programme is the human factor. Harris & Chaney (1969) treat this entire subject in their text *Human Factor in Quality Assurance*. This text is recommended to the reader interested in all aspects of the human factor in quality assurance. The remainder of this section will focus on the human factor variable as it is of peculiar significance in the consideration of a quality assurance programme for the construction of a hazardous waste disposal facility.

Through its permit issuing agency, the EPA can be assured that the desired standard of quality is designed for by the permittee. But what assurance is there that the standard of quality contained in the design is achieved in the construction and operation of the facility?

The permittee suffers from an inherent conflict of interest in the fulfillment of his construction and operations responsibilities *vis-à-vis* the fulfillment of his quality assurance responsibilities. Possible manifestations of this conflict of interest are obvious. What does the permittee do when told by his quality inspector that an entire block of work is rejected and must be done again because it is just barely below the standard of quality in the design? What does the permittee do when motivated by the opportunity to maximize profits and believing to himself that government approved designs always include an excessive margin of safety?

This conflict of interest, this human factor, must be addressed in an effective quality assurance programme.

5.1.5. *The problem of scale*

As stated earlier, the permittee of a hazardous waste disposal facility is somewhat unique. Although there are other organizations in the construction industry which also have all these responsibilities (design, construction and operations, and quality assurance) and thus are similar in concept, there exist significant differences between these organizations because of the problem of scale. An example of such a seemingly similar organization is that of an organization constructing a nuclear power facility.

In the construction of a nuclear power facility a large organization, which might be considered an institution, has the three responsibilities. In order to protect the reputation of the organization, the present and future jobs of its employees, the huge financial stake in the project, and the professional status of its engineers, this institution has many positive motivators to achieve the standard of quality contained in the design. In order to avoid the adverse consequences of all possible future litigation, the institution also has a strong negative motivator to achieve the standard of quality contained in the design.

In the construction of a hazardous waste disposal facility, it is entirely possible for a very small organization to have all three responsibilities above. Hypothetically, that small organization could be dominated by one individual. Thus, this hypothetical organization would act less like an institution and more in a manner reflective of the

dominant individual's personality. Thus this organization might be willing to cut corners and take risks. The standard of quality achieved by the organization would then be that set by the dominant individual and not that contained in the design.

So although the two organizations described above are similar in concept, in that both have all three responsibilities, there exists the real likelihood that they might differ in action because of their dissimilarity in size (the problem of scale).

5.2. *The quality assurance plan*

It is recommended that the permittee develop a formal, written plan of action for implementing a quality assurance programme. This should include such items as: an organization plan; details of quality assurance methods; names and qualifications of individuals for quality assurance; the procedures for review of data; procedures for reporting; and procedures for assigning responsibility.

5.3. *Quality assurance documentation*

Considering all of the factors discussed above, it is recommended that the following documentation of tests and observations be made.

(1) Daily inspection reports.
(2) Data sheets for all tests and observations.
(3) Block evaluation reports, showing all data and statistical analyses.
(4) Design acceptance reports, presenting a review of the block reports and their comparison with design requirements.
(5) A summary and checklist for each major section of the project made after its completion.

The documentation programme given above is intended to provide (a) motivation for an effective quality assurance programme, (b) data in the event of remedial action being required in the future, and (c) factual information in the event of litigation.

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